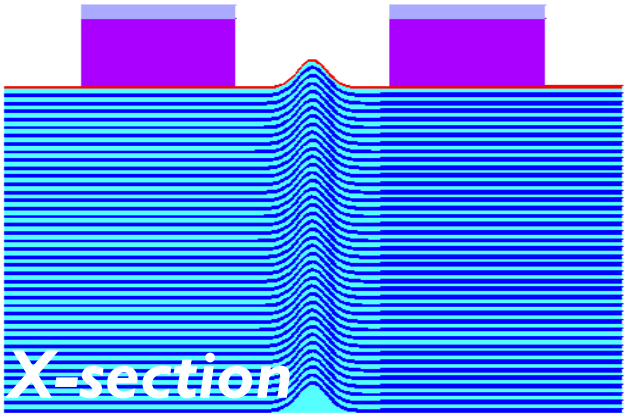
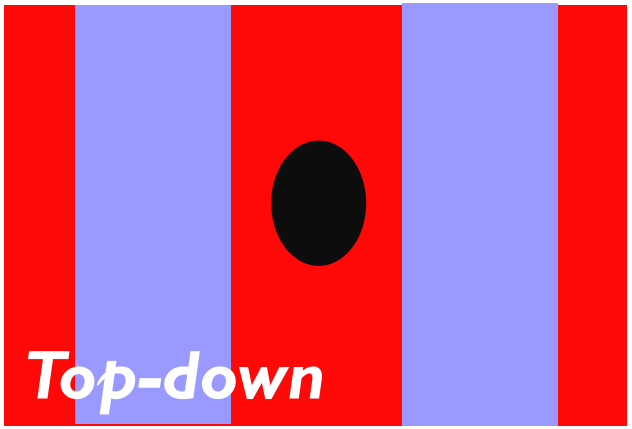
STUDY OF MULTILAYER DEFECTS ON SUB-32NM HP EUV RETICLES

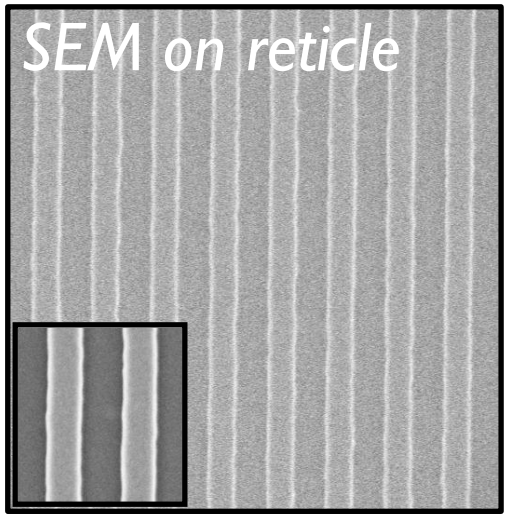
DIETER VAN DEN HEUVEL [A], RIK JONCKHEERE [A], TRISTAN BRET [B], MARKUS WAIBLINGER [B]

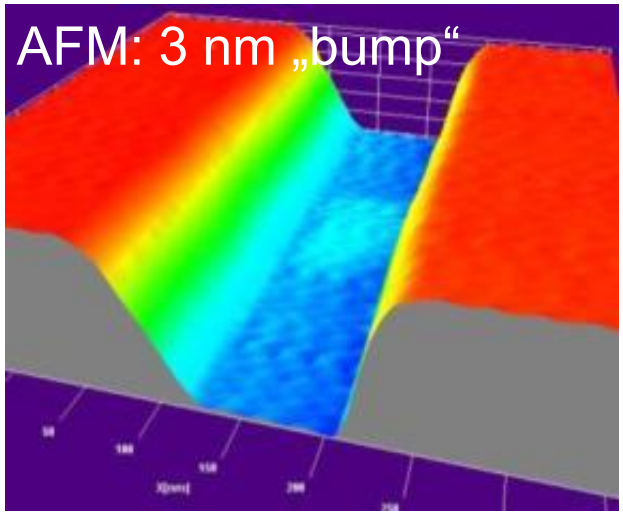
[A] IMEC, [B] CARL ZEISS SMS

INTRODUCTION
ML-DEFECTS

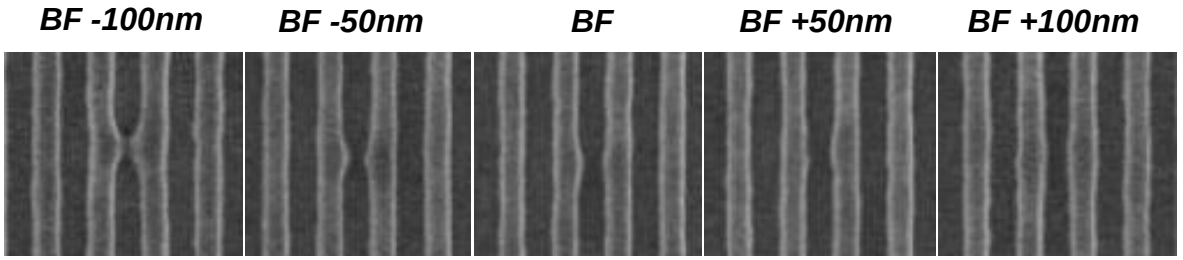








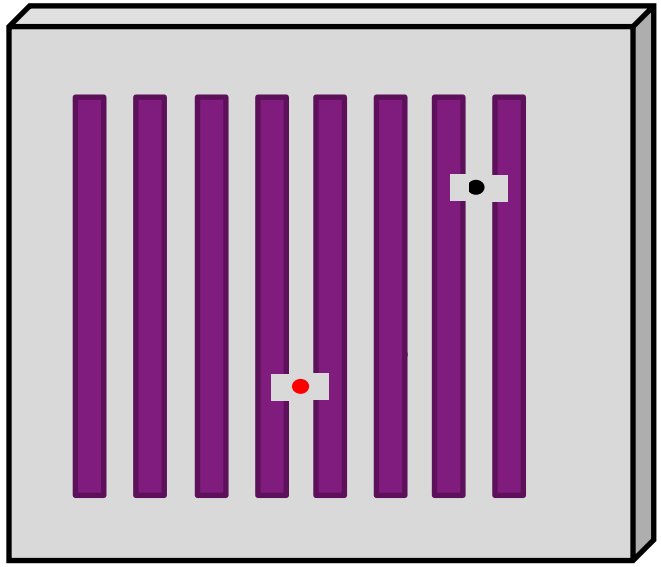
On wafer



INTRODUCTION
ML-DEFECTS STRATEGY

Final goal needs to be 0-defect blanks, but on short term a "safety net" needs to be available.

1. ***Adequate BI*** to detect as many printing blank defects as possible
2. Try to cover printing blank defects with absorber ***(mitigation by pattern shift)***
3. Repair of defects that cannot be covered ***(compensation repair)***
4. Repair of Blank defects missed by BI

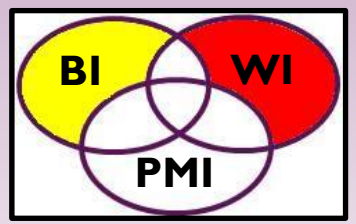


Ref.: EUVL Multilayer Mask Blank Defect Mitigation for Defect-free EUVL Mask Fabrication (Pei-Yang Yan, SPIE-2012)

INTRODUCTION
CHALLENGES

1. Inspection (Optical)

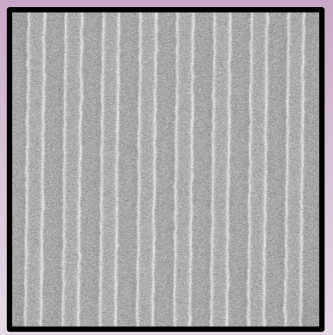
- limited penetration depth in mirror
- difficult to predict printability of defect



⇒ **ML defects only found by WI**

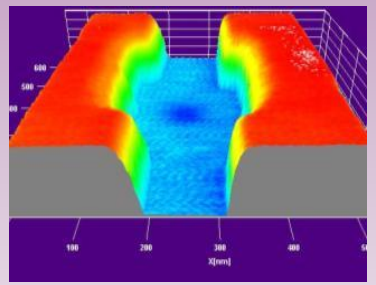
⇒ **Many detections BI don't print**

2. Visualization



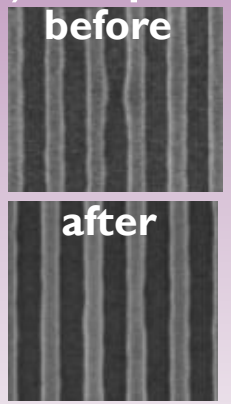
- In anticipation of AIMS, (integrated) AFM is essential
- Small trenches, contacts become challenge

3. (Compensation) Repair

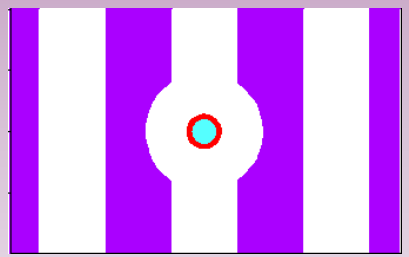


Reticle AFM

wafer



4. Simulation



Learning:

- Shape, size, propagation, ...
- Limitations

INTRODUCTION
CHALLENGES

1. Inspection (Optical)

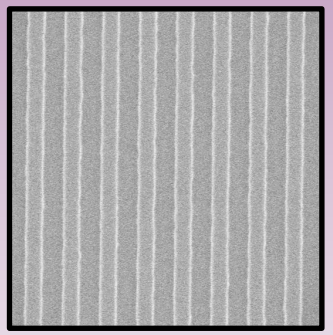
- limited penetration depth in mirror

See poster: "Improvements of Multi-Layer Defect Mapping with Advanced Inspection Technology", Lior Shoval et al.

⇒ ML defects only found by ...

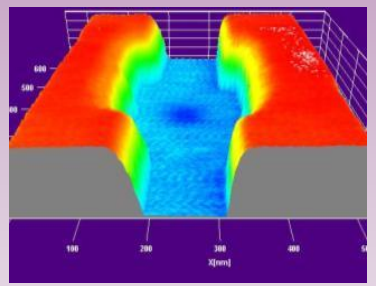
⇒ Many detections BI don't print

2. Visualization



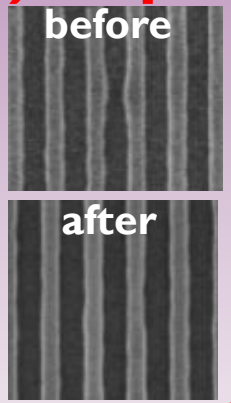
- In anticipation of AIMS, (integrated) AFM is essential
- Small trenches, contacts become challenge

3. (Compensation) Repair



Reticle AFM

wafer



4. Simulation

See presentation: "Rigorous Modeling and Optimization of Multilayer Defect Repair", A. Erdmann et al.

Learning:
- Shape, size, propagation, ...
- Limitations

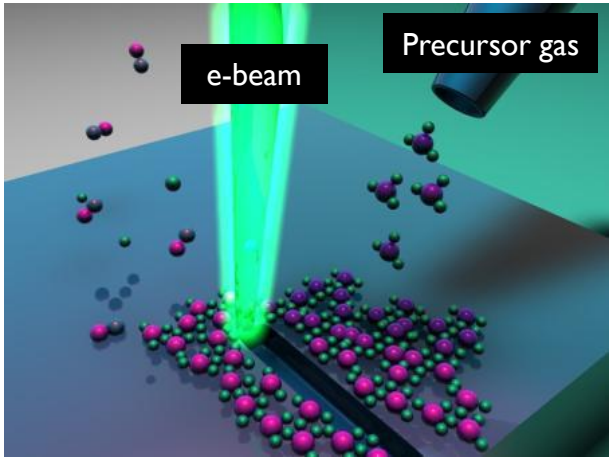
So far results were obtained on 40/32nm L/S

(see R. Jonckheere et al. EUVL 2011)

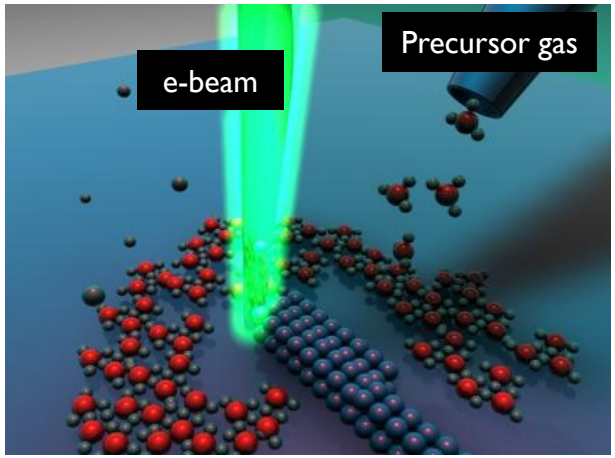
OUTLINE

- Lines and spaces: 27nm and 25nm HP
  - *Is it still possible to visualize ML defects <10nm high when the trenches become smaller?*
  - *How realistic is compensation repair with these dimensions?*
- Contact Holes: 30nm HP
  - *Even more challenging for AFM*
  - *How to perform compensation repair on contacts?*

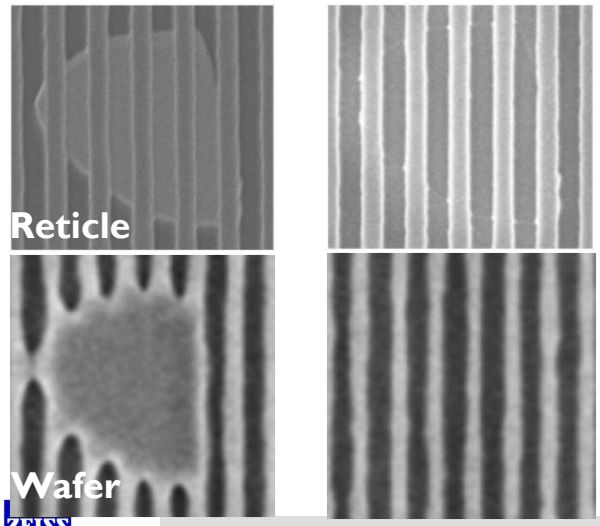
CARL ZEISS MeRiT® HR TECHNOLOGY
E-BEAM BASED REPAIR

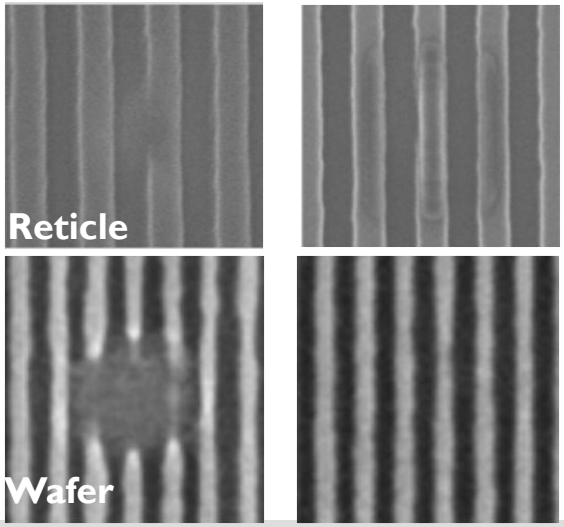


Etching: volatilization of material
Used for opaque absorber defects

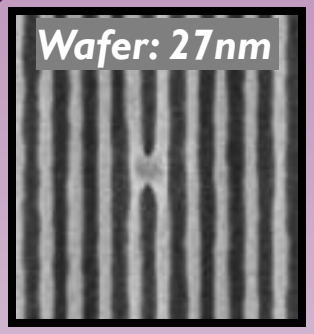


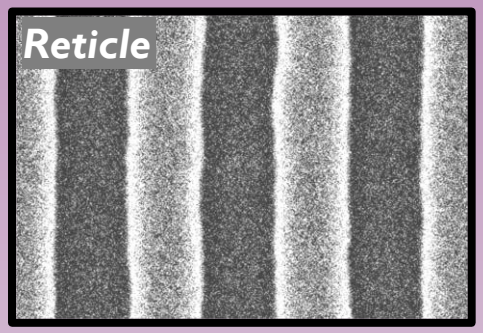
Deposition: Immobilization of precursor
Used for clear absorber defects

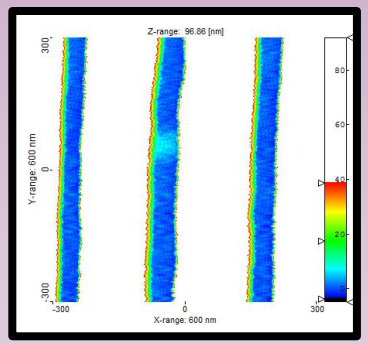




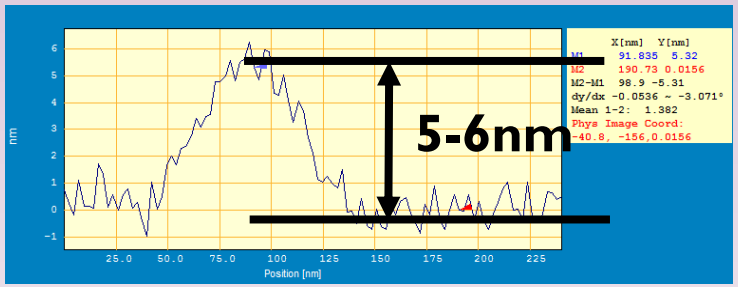
REPAIR ML DEFECTS ON 2XNM L/S
I) VISUALIZATION

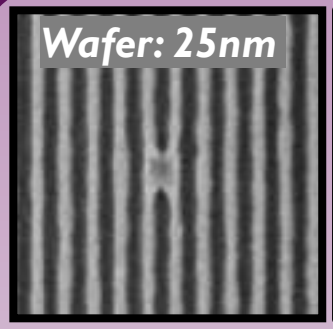


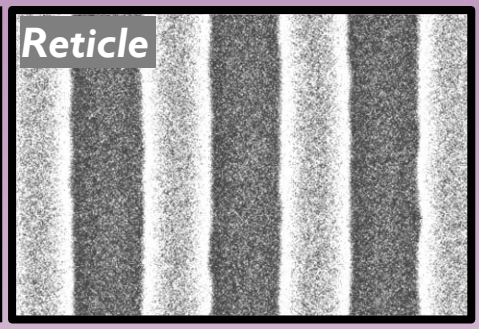


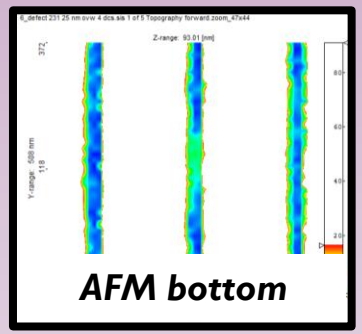


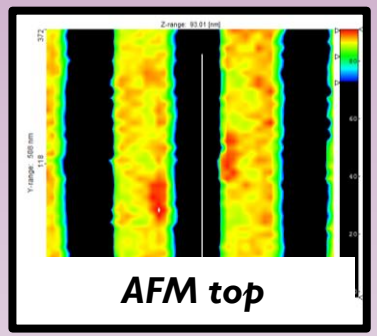
MeRiT® HR
Integrated AFM

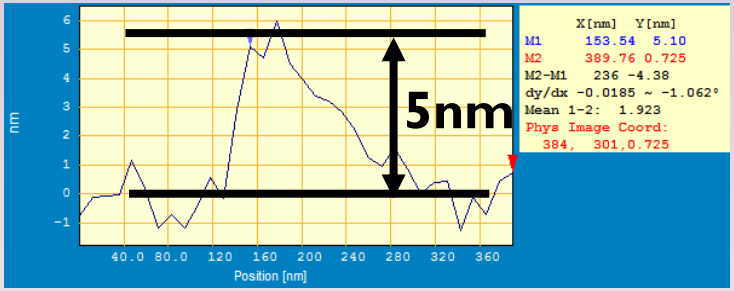






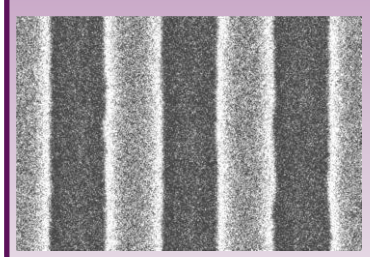


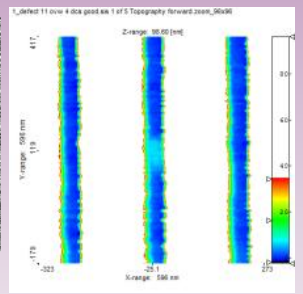


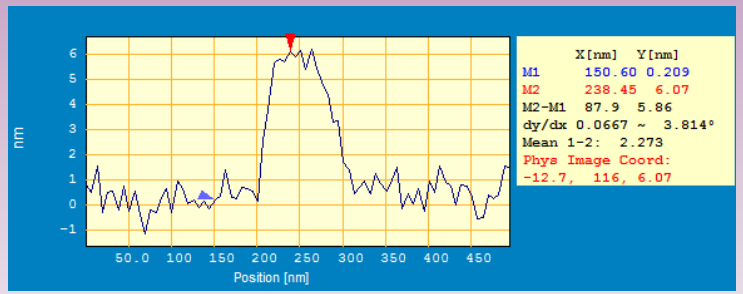


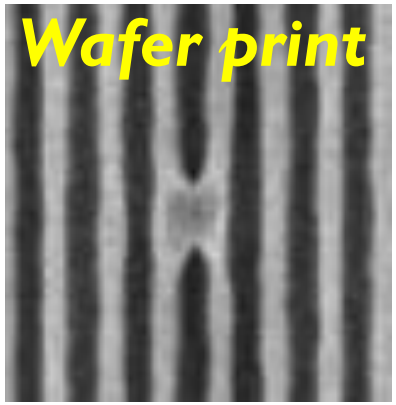
REPAIR ML DEFECTS ON 2XNM L/S
2) COMPENSATION REPAIR

Mask review before repair

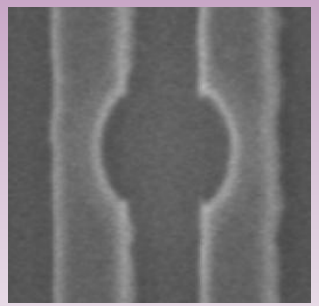


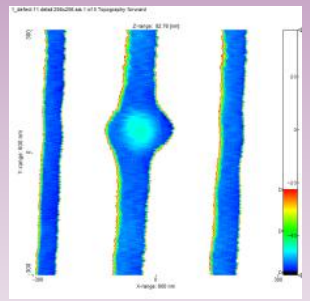


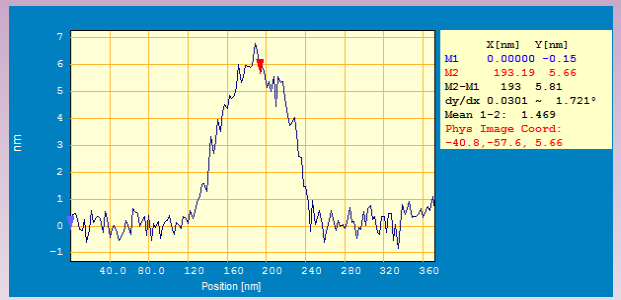


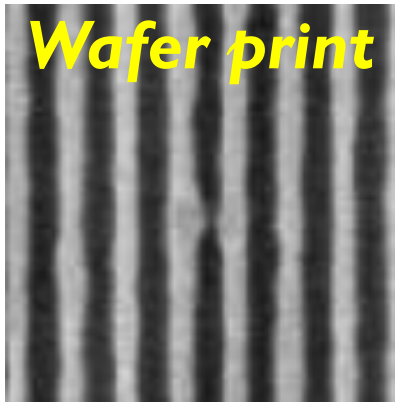


Mask review after compensation repair







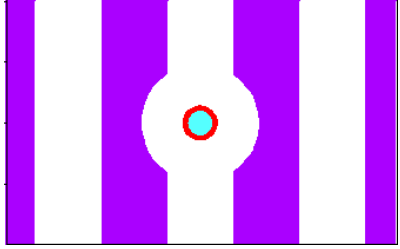


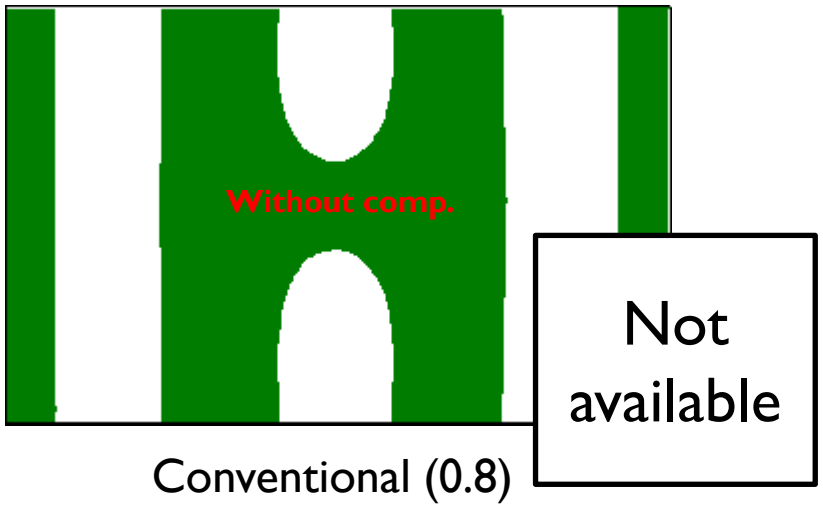
What is the influence of off axis illumination (dipole 60X sigma 0.8/0.4)?

REPAIR ML DEFECTS SIMULATION

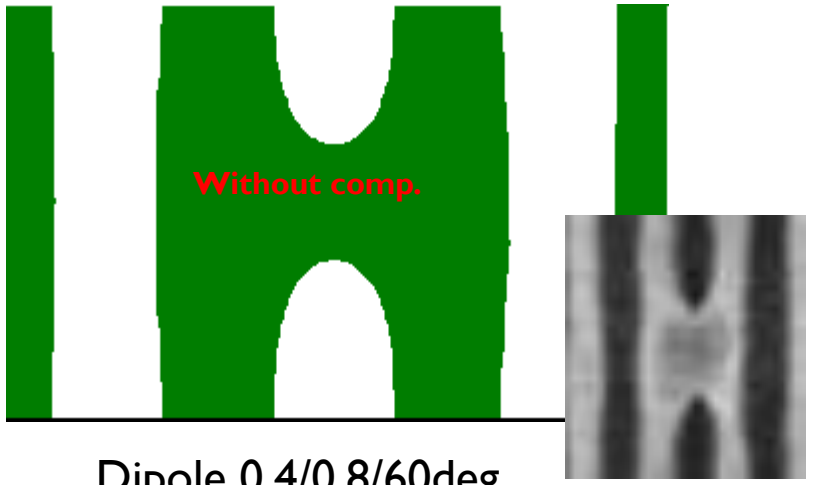
S-LITHO EUV

Bump 6nm, 27nm L/S
40nm FWHM, BF

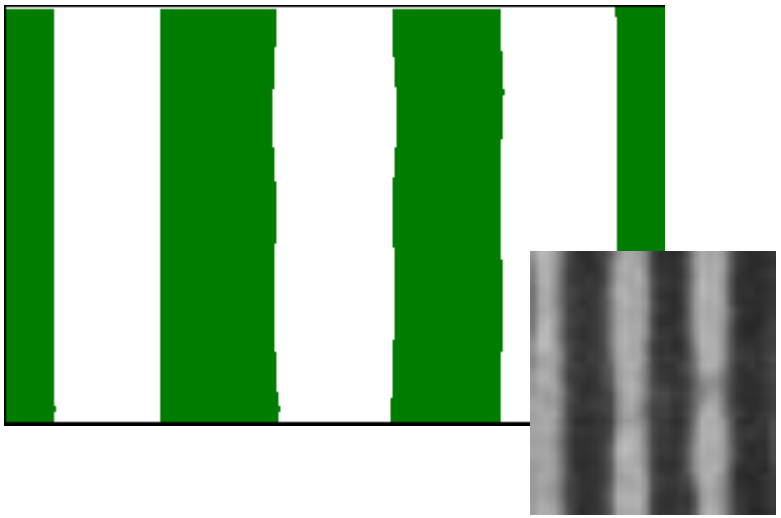


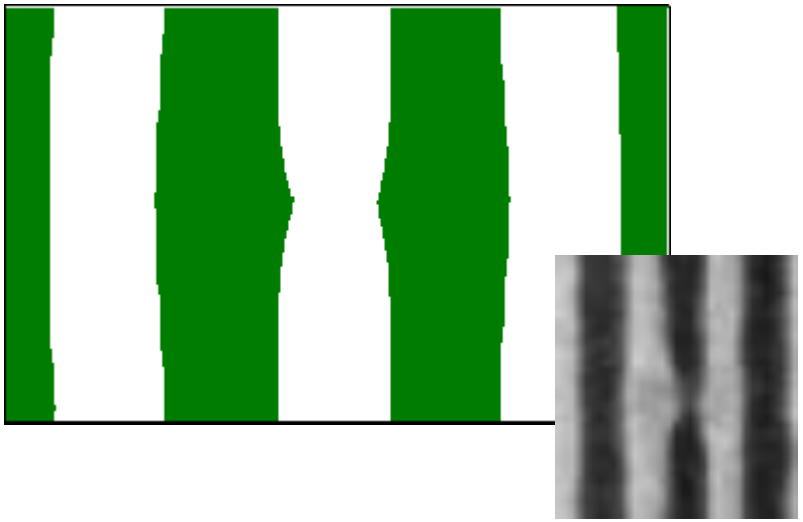


Conventional (0.8)



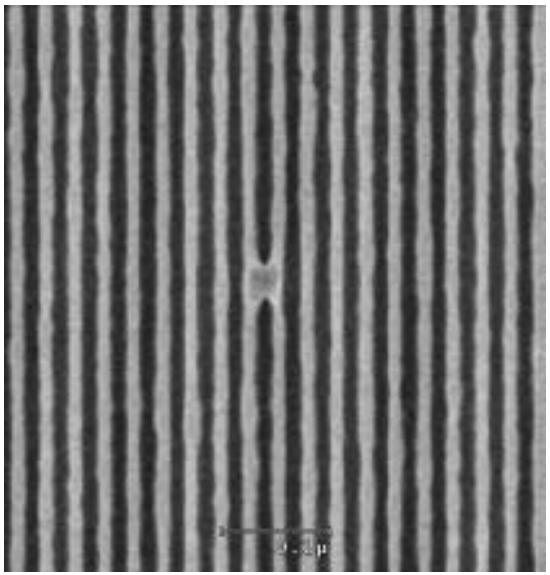
Dipole 0.4/0.8/60deg



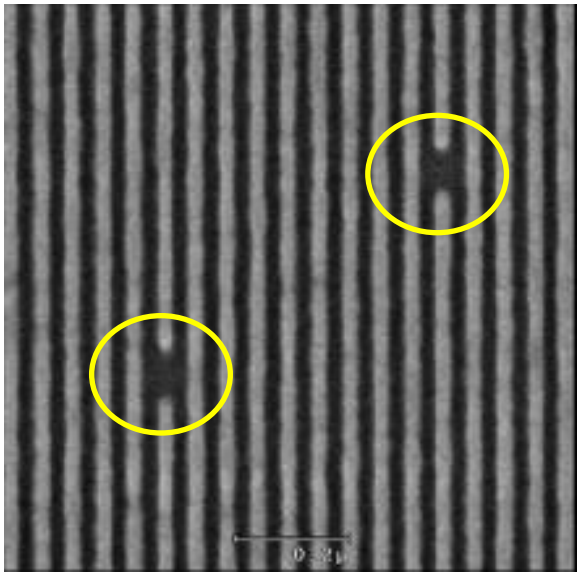


COMPENSATION REPAIR ON 27NM L/S

Reference (BF)
(dipole)



After repair (BF)
(conventional)



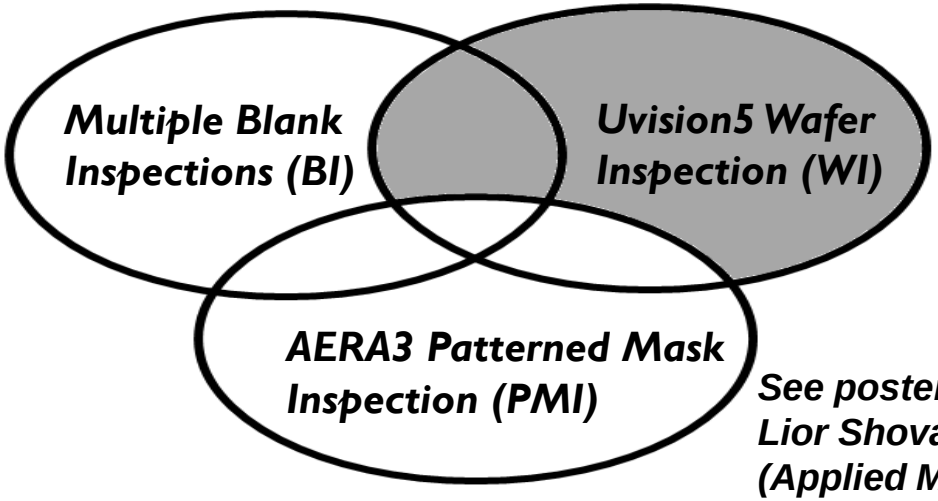
Note: markers only placed to be able to know exact location on wafer

OUTLINE

- Lines and spaces: 27nm and 25nm HP
  - *Is it still possible to visualize ML defects <5nm when the trenches become smaller?*
  - *How realistic is compensation repair with these dimensions?*
- Contact Holes: 30nm HP
  - *Even more challenging for AFM*
  - *How to perform compensation repair on contacts?*

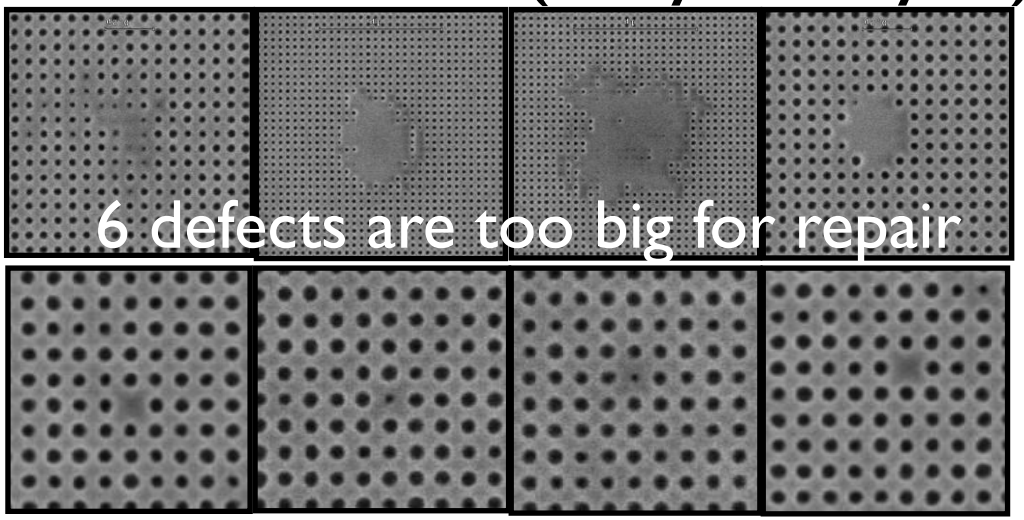
EXPERIMENTAL SETUP

- *Large area covered with 30nm dense CH*
- *Focus on natural defects*

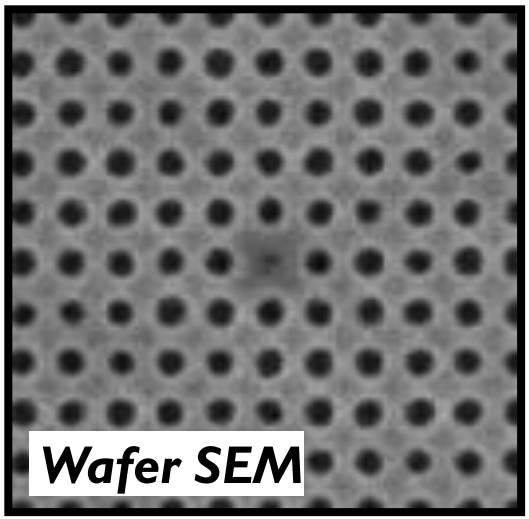


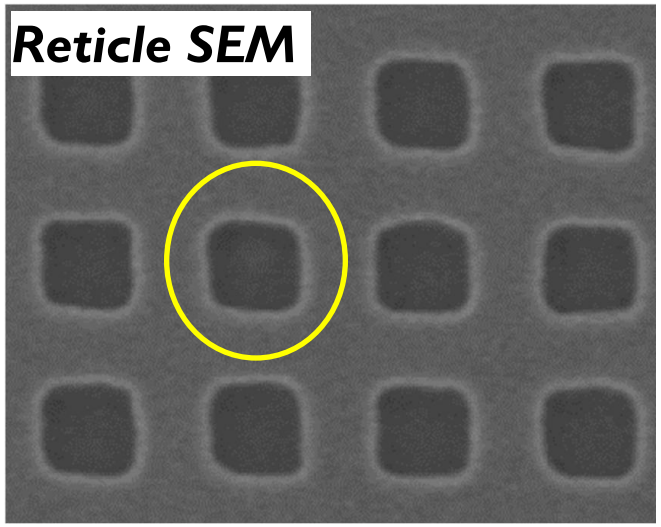
See poster P-MA-23, Lior Shoval et al. (Applied Materials)

Total of 29 ML defects (8 only found by WI)

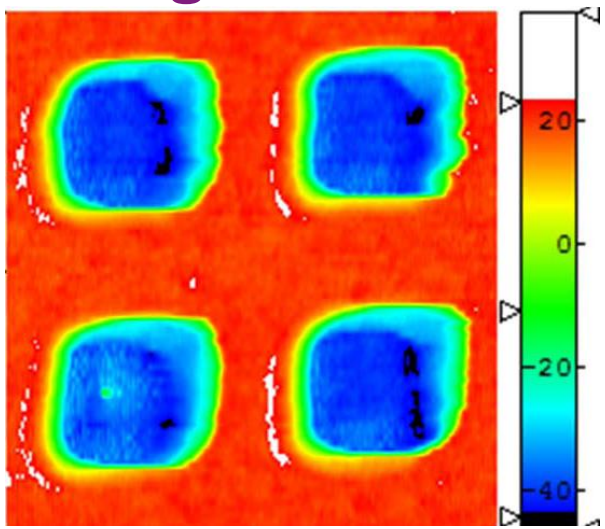


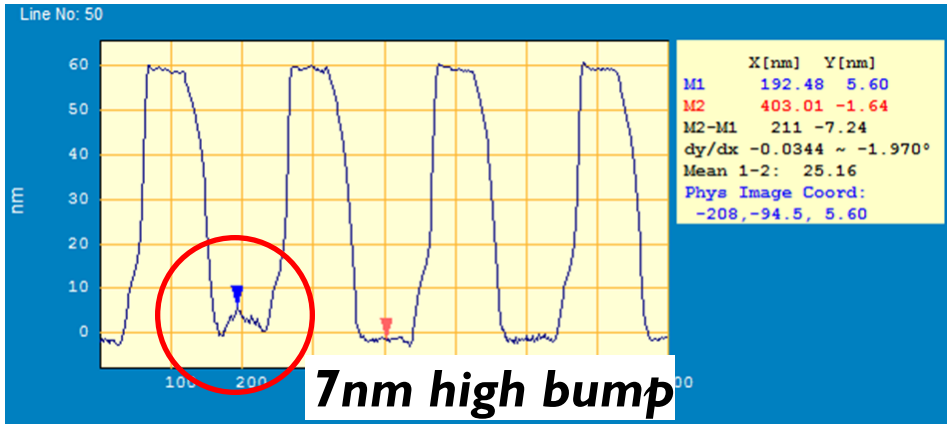
REPAIR ML DEFECTS ON 30NM CH
I) VISUALIZATION



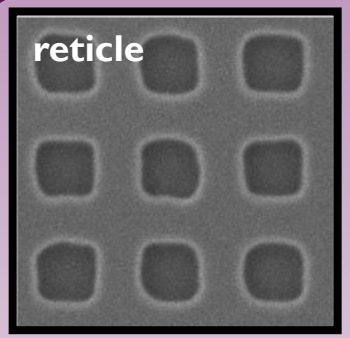


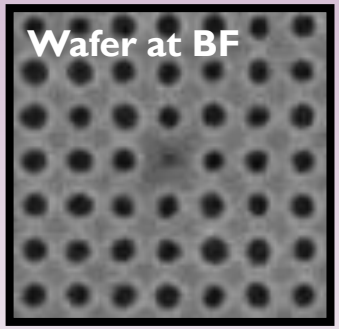
Mask Review with Integrated AFM



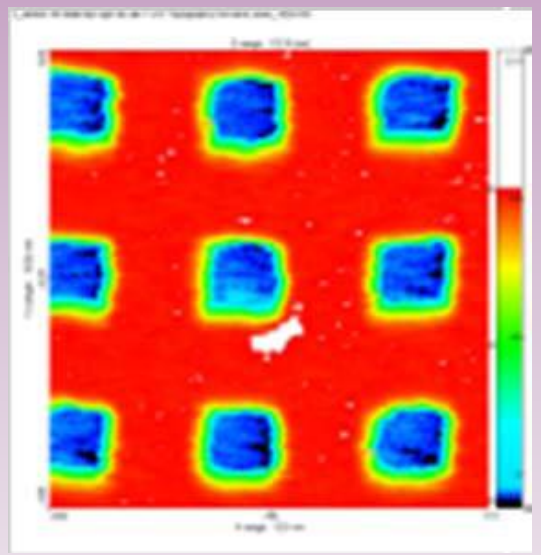


REPAIR ML DEFECTS ON 30NM CH
2) REPAIR

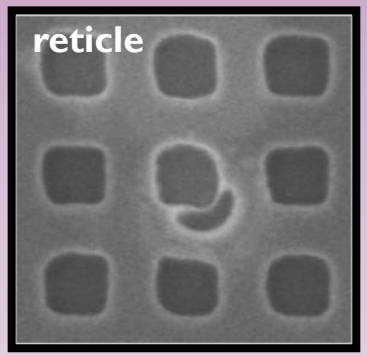


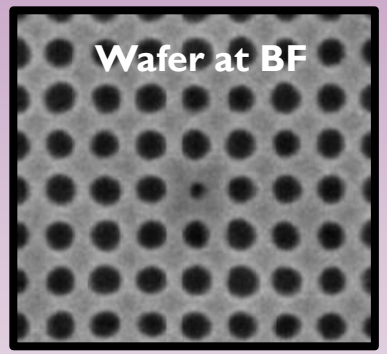


Before repair



After e-beam repair

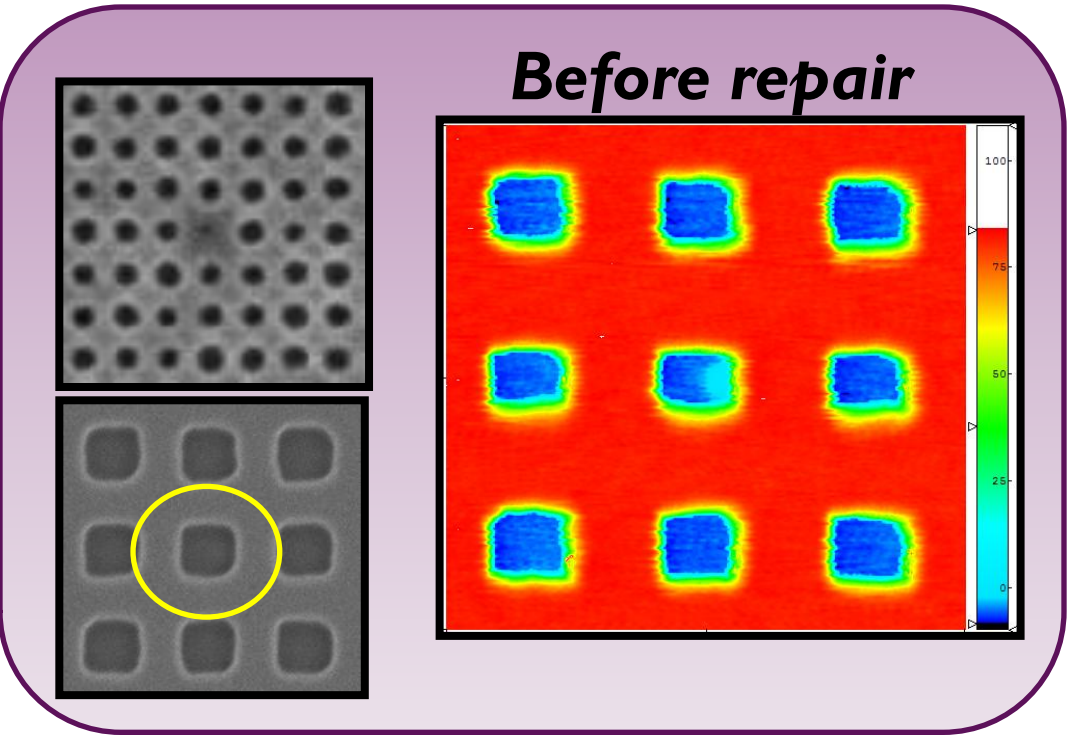


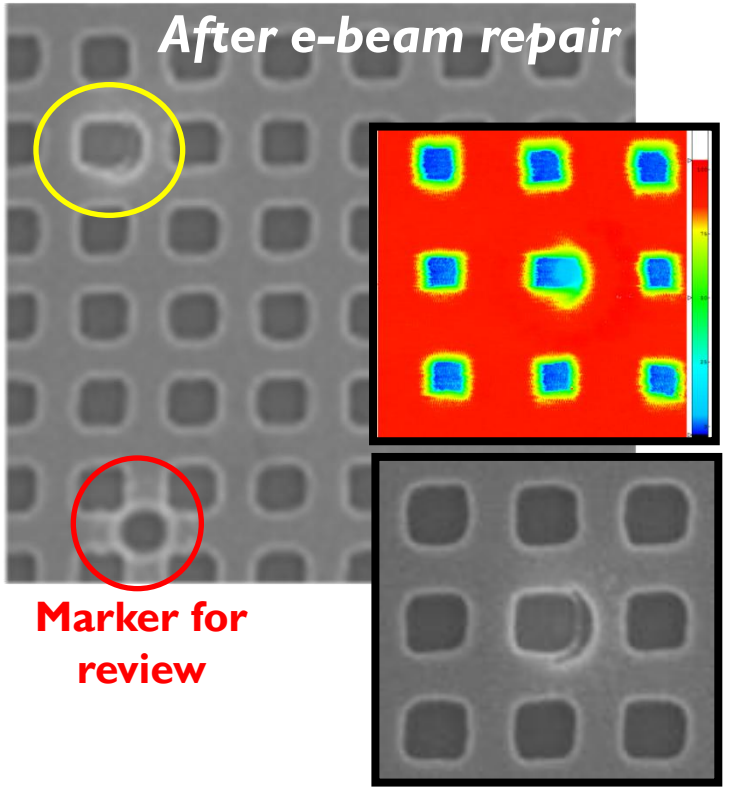


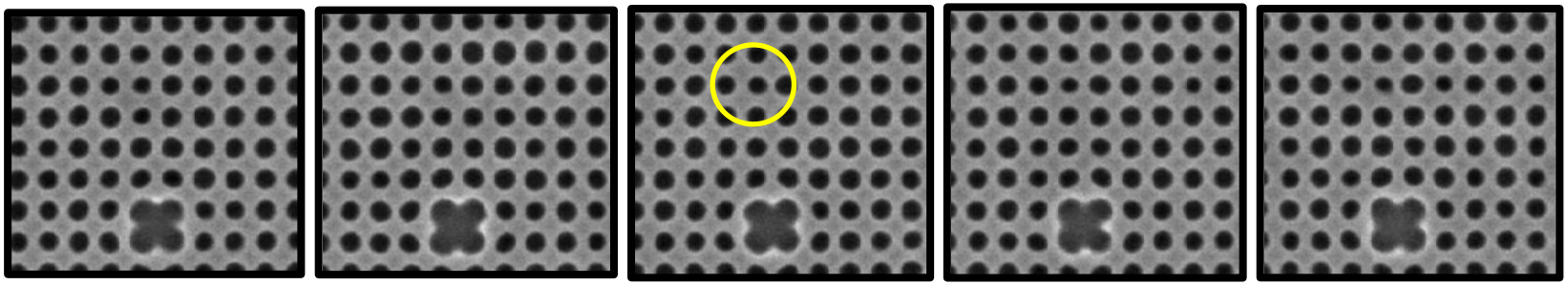
Observations on this example:

- Wafer **print is improved**, yet not satisfactorily
- **Rework** is possible
- **limited** compensation **process window** on this BI-found ML bump (see also presentation A. Erdmann)

REPAIR ML DEFECTS ON 30NM CH
3) SUCCESSFUL REPAIR







CONCLUSIONS

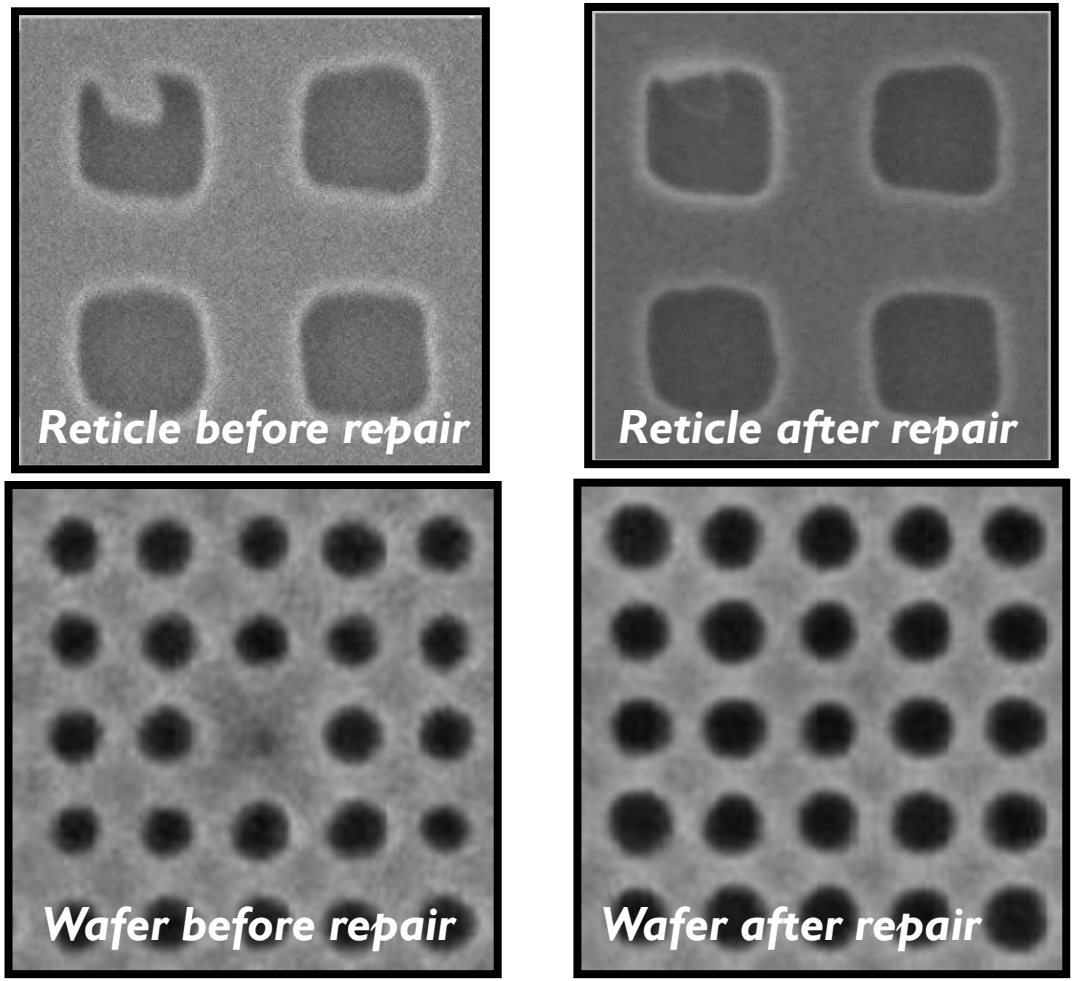
- **Final goal should remain 0-defect blanks, but compensation repair can provide back-up scenario**
  - One repair shape cannot compensate reflection loss for each **illumination setting**
  - Certain **defect characteristics inside the ML** can limit compensation process window (AIMS)

    Note: Current repairs focused on fairly **solid bumps found by BI**
    => next step will be more **subtle defects found by WI** only

- **E-beam repair on 2Xnm L/S + 30nm dense CH:**
  - ***Repair strategies and techniques*** **developed on** ***4X and 3X*****nm features are still valid, including** ***compensation repair***
  - ***AFM's*** **continued value is demonstrated**

APPENDIX

REPAIR ON 30NM CH OPAQUE ABSORBER DEFECTS



REPAIR ON 30NM CH
FOREIGN MATERIAL REMOVAL